STATUS OF THE CLAIMS

1. (Previously Presented) A vertical alignment mode liquid crystal display apparatus comprising:

a pair of substrates opposing each other;

a liquid crystal layer interposed between the pair of substrates, the liquid crystal layer containing liquid crystal molecules having a negative dielectric anisotropy; at least one electrode provided on each of the pair of substrates, the at least one electrode being used for applying an electric field across the liquid crystal layer; and

at least one volume excluding member,

wherein: one of the at least one volume excluding member is provided on the at least one electrode on at least one of the pair of substrates, the volume excluding member being provided so as to be on at least a portion of one side edge of the at least one electrode;

a side of each of the pair of substrates facing the liquid crystal layer is subjected to a vertical alignment treatment; and

the liquid crystal molecules are tilted in a uniform direction from the at least one side edge of the at least one electrode to an opposite edge when a voltage is applied to the at least one electrode.

2. (Original) A liquid crystal display apparatus according to claim 1, wherein the volume excluding member comprises at least one of a protrusion and a concave stepped portion.

3. (Withdrawn) A liquid crystal display apparatus according to claim 1, wherein the volume excluding member is provided alone the entirety of the at least one side edge of the at least one electrode.

4. (Previously Presented) A vertical alignment mode liquid crystal display apparatus comprising:

a pair of substrates opposing each other;

a liquid crystal layer interposed between the pair of substrates, the liquid crystal layer containing liquid crystal molecules having a negative dielectric anisotropy; at least one electrode provided on each of the pair of substrates, the at least one electrode being used for applying an electric field across the liquid crystal layer; and

a plurality of volume excluding members provided on the at least one electrode on at least one of the pair of substrates, each of the plurality of volume excluding members being provided so as to be on at least a portion of each of an opposing pair of side edges of the at least one electrode but so as not to oppose each other, wherein:

a side of each of the pair of . substrates facing the liquid crystal layer is subjected to a vertical alignment treatment; and

the liquid crystal molecules are tilted in a uniform direction from the at least one side edge of the at least one electrode to an opposite edge when a voltage is applied to the at least one electrode.

5. (Original) A liquid crystal display apparatus according to claim 4, wherein:

the at least one electrode on the at least one of the pair of substrates includes a first side edge and a second side edge; and

the plurality of volume excluding members are provided alone a portion of the first side edge and along a portion of the second side edge.

6. (Original) A liquid crystal display apparatus according to claim 4, wherein a non-conductive window portion is formed n the at least one electrode on the at least one of the pair of substrates.

7. (Previously Presented) A vertical alignment mode liquid crystal display apparatus comprising:

a pair of substrates opposing each other;

a liquid crystal layer interposed between the pair of substrates, the liquid crystal layer containing liquid crystal molecules; and

at least one electrode provided on at least one of the pair of substrates, the at least one electrode being used for applying an electric field across the liquid crystal layer,

wherein:

the liquid crystal layer includes at least one pixel portion and a non-pixel portion, the at least one pixel portion corresponding to the at least one electrode; and

when voltage is not applied to the at least one electrode, the liquid crystal molecules in the at least one pixel portion are oriented in a vertical alignment and the liquid crystal molecules in the non-pixel portion are oriented in a uniaxial horizontal alignment.

8. (Original) A liquid crystal display apparatus according to claim 7, wherein the liquid crystal molecules in the at least one pixel portion are oriented in a horizontal alignment so as to be tilted in a uniform direction when a voltage is applied to the at least one electrode.

9 (Original) A liquid crystal display apparatus according to claim 8, wherein a volume excluding member is formed on a portion of the at least one electrode.

10. (Original) A liquid crystal display apparatus according to claim 9, wherein the volume excluding member comprises at least one of a protrusion and a concave stepped portion.

11. (Original) A liquid crystal display apparatus according to claim 8, wherein a side of the at least one of the pair of substrates facing the liquid crystal layer is subjected to a rubbing treatment.

12. (Original) A liquid crystal display apparatus according to claim 8, wherein the at least one electrode comprise a comb electrode.

13. (Original) A liquid crystal display apparatus according to claim 7, wherein the liquid crystal molecules in the non-pixel portion are oriented in a uniaxial horizontal alignment by at least one method selected from the group consisting of : subjecting a horizontal alignment film to a rubbing treatment; subjecting a vertical alignment film to a selective chemical modification treatment followed by a rubbing treatment; subjecting a vertical alignment film to a selective irradiation of ultraviolet rays followed by a rubbing treatment; and subjecting a vertical alignment film to an irradiation of selectively polarized ultraviolet rays.

14. (Original) A liquid crystal display apparatus according to claim 8, wherein a direction of the horizontal alignment of the liquid crystal molecules in the at least one pixel portion is substantially identical to a direction of uniaxial horizontal alignment of the liquid crystal molecules in the non-pixel portion.

SUMMARY OF THE INVENTION

The present invention is directed to a liquid crystal display ("LCD") apparatus that **operates on the vertical alignment ("VA") mode**, in which, in the absence of an applied voltage, the liquid crystal molecules are vertically aligned and, in the presence of applied voltage, are horizontally aligned. Indeed,

> [a]ccording to VA mode, an LC material having a negative dielectric anisotropy $\Delta\varepsilon$, which is originally oriented in a vertical alignment, may be realigned in a horizontal alignment responsive to an electric field applied between substrates. Alternatively, an LC material having a positive dielectric anisotropy $\Delta\varepsilon$, which is originally oriented in a vertical alignment, may be realigned in a horizontal alignment responsive to an electric field applied in a direction parallel to the substrate surfaces.

Specification, page 34, lines 15-25. As a result, birefringence is virtually eliminated because, **in an initial state, the LC material is vertically aligned**, providing "an excellent dark display state". See, e.g., Id., page 35, lines 2-5.

Display apparatuses that function based on VA mode of liquid crystalline molecules are significantly different from display apparatuses that function based on twisted nematic ("TN") mode in which the twist of liquid crystal molecules are altered in response to applied voltage. Moreover, application of a voltage to a TN mode apparatus typically induces rotation or twisting of the liquid crystalline molecules without changing the tilt of the molecules relative to the surface. Thus, the vertical orientation of the liquid crystalline molecules in a TN mode liquid crystal display apparatus is not essential to the cell or pixel operation.

Disadvantageously, the VA mode

> is susceptible to disclination * * * in which <u>random discontinuities in orientation</u> (i.e., "disclination") arise in response to an applied electric field <u>causing LC molecules to be tilted in an omnidirectional manner</u>.

Id., page 35, lines 14-22 (emphasis added). Disclination **slows the response speed** of the LCD apparatus. See, e.g., Id., page 36, lines 16-19. However, LC cells having disclination controlled to be a one-dimensional shape have a faster response speed than LC cells having disclination controlled to be a two-dimensional shape. See, e.g., Id., page 36, line 20 to page 37, line 5. The inventors presume that, response speed is inversely proportional to disclination. See, e.g., page 38, lines 10-13.

Prior art attempts to address problems caused by disclination have included forming protrusions on a substrate to control the tilting direction of the LC molecules and/or providing a control electrode around the pixel electrode to control the orientation of the LC molecules. See, e.g., Id., page 36, lines 4-12. Other prior art attempts have included pre-tilting the LC molecules from completely vertical using, e.g., slanted portions in the substrate and/or "subjecting a vertical alignment film to a rubbing treatment." See, e.g., Id., page 38, lines 17 to page 39, line 4. However, **a less than perfectly vertical initial state detracts from the dark display state**. See, e.g., Id., page 39, lines 2-4.

Accordingly, the invention as claimed provides

> a mode of switching which retains a substantially perfect vertical alignment in an initial state and which can prevent disclination, in order to make full use of the high contrast and fast response potentials of the VA mode.

Id., page 39, lines 7-11 (emphasis added).

In a first embodiment, a" volume excluding member", e.g., a protrusion 114, is provided on one side edge of each electrode 103, which controls the tilting orientation of the LC molecules, avoiding disclination. Specifically, as illustrated in Figure 1B, **all of the LC molecules are oriented, i.e., tilted, in the same direction** except for those LC molecules in a non-pixel portion of the LC cell. More specifically, the LC molecules **have a one-dimensional disclination**. Alternatively, in a second embodiment, a "volume excluding member", e.g., a

concave stepped portion 216, is provided along one side edge of each electrode 203 to control the tilting orientation of the LC molecules. Once again, as illustrated in Figure 2B, **all of the LC molecules are oriented, i.e., tilted, in the same direction** except for those LC molecules in a non-pixel portion of the LC cell and the LC molecules **have a one-dimensional disclination.**

The present invention also addresses problems due to viewing angles in the following manner:

> protrusions 414 or concave stepped portions (not shown) may be provided along portions of two opposite side edges of each pixel in such a manner that the protrusions 414 or concave stepped portions (not shown) do not oppose each other, thereby preventing LC molecules 415 moving in opposite directions from colliding with each other in the central portion of each pixel. As a result, the LC molecules 415 can be caused to move in two directions that are 180° apart, without allowing disclination to occur. Thus, the viewing angle characteristics in either the right-left or up-down direction can be improved while maintaining fast response.

Id., page 42, line 17 to page 43, line 4 (emphasis added).

Likewise, a pixel can be divided into a plurality, e.g., four, of sub pixel regions, having protrusions or stepped concave portions disposed on four different sub pixel side edges, none of which are directly opposite the others. See, e.g., FIGs. 5 and 6. When an electric field is applied to the pixel, the "LC molecules can be caused to move in four different directions, 90° apart, without allowing disclination to occur." Id., page 43, lines 22-25 (emphasis added).